

COMMUNICATIONS BRANCH
SUBMARINE MEDICAL CENTER
FILE COPY NO. 2



**U. S. NAVAL SUBMARINE
MEDICAL CENTER**

Submarine Base, Groton, Conn.

REPORT NUMBER 639

PROBLEMS OF VOICE COMMUNICATION IN THE NAVY:

Regulation of Vocal Intensity at Low Fundamental Frequencies

by

Thomas Murry

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF12.524.004-9011D.05

Released by:

J.E. Stark, CAPT MC USN
Commanding Officer
Naval Submarine Medical Center

24 August 1970



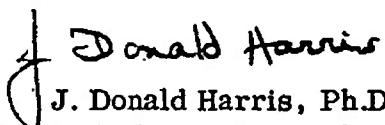
PROBLEMS OF VOICE COMMUNICATION IN THE NAVY:
REGULATION OF VOCAL INTENSITY AT LOW FUNDAMENTAL FREQUENCIES

by
Thomas Murry

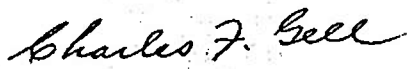
SUBMARINE MEDICAL RESEARCH LABORATORY
U.S. NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 639

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MF12.524.004-9011D.05


Transmitted by:


J. Donald Harris, Ph.D.
Head, Auditory Research Branch

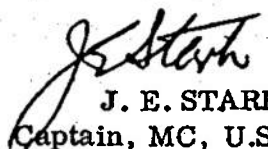
Reviewed and Approved by:


Charles F. Gell, M.D., D.Sci. (Med)
Scientific Director,
SubMedResLab

Reviewed and Approved by:


J. D. Bloom, CDR, MC, USN
Officer-in-Charge
SubMedResLab

Approved and Released by:


J. E. STARK
Captain, MC, U.S. Navy
COMMANDING OFFICER, SUBMEDCEN

This document has been approved for public release and sale;
its distribution is unlimited.

SUMMARY PAGE

THE PROBLEM

To investigate voice distortion which may be encountered by Naval diving personnel under conditions of high pressure. This study investigated the intensity parameter of extremely low frequency phonation.

FINDINGS

The findings indicate that low frequency phonation is produced at intensities lower than those recorded for normal conversational speech and furthermore, unlike normal conversational speech there appears to be an interrelationship between changes in frequency and intensity.

APPLICATION

The information in this report provides a basis for greater understanding of the phonatory processes of a person's phonational range. In addition, the results provide preliminary data for investigations of the efficiency of vocal usage in environments where there is increased ambient pressure or increased oral constriction such as that encountered with the addition of a diving mask or breathing apparatus used by diving personnel in the Navy.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF12.524.004-9011D - Procedures for Improving Underwater Verbal Communications Capabilities in Submarines and Deep Submergence Systems. The present report is No. 5 on the above work unit. It was approved for publication on 24 August 1970 and designated as Submarine Medical Research Laboratory Report Number 639.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL CENTER

ABSTRACT

Previous investigations indicate that as one approaches the upper or lower limits of the modal or falsetto phonational registers, the range of vocal intensities the speaker is capable of producing decreases. However, no data are available relating frequency/intensity changes for extremely low frequency phonation, often called glottal or vocal fry due to its perceptual attributes. The purpose of this study was to determine the relationship between fundamental frequency and vocal intensity during low frequency phonation. Subjects sustained the low frequency pulse-like phonation for three seconds at three points in their total low frequency range and the intensity recorded. Thereafter, the subjects sustained glottal fry at the three recorded intensities previously obtained and the fundamental frequency recorded. The findings indicate that glottal fry is produced at low intensities in relation to intensity levels noted by previous investigators for the modal and falsetto registers. Furthermore, it appears that frequency and intensity changes for normally sustained low frequency phonation are inter-dependent. Finally, combined results of this and previous studies indicate that the predominant frequency/intensity changing mechanism for this normal but low frequency phonation is subglottal air pressure.

PROBLEMS OF VOICE COMMUNICATION IN THE NAVY:

REGULATION OF VOCAL INTENSITY AT LOW FUNDAMENTAL FREQUENCIES

INTRODUCTION

The relationship between vocal intensity and fundamental frequency of phonation in the modal and falsetto registers has been investigated by Colton¹ and Colton and Hollien². These authors concluded that the intensity range in the modal register is greater than that in falsetto. They further noted that the greatest intensity variation of fundamental frequency occurs at the middle of the modal and falsetto phonational ranges. These results were consistent with the findings of Stout³ indicating that as a speaker approached the lowest frequency of the modal register, his intensity range decreased until no intensity variation was possible. The implication from these studies appears to be that as one increases or decreases his fundamental frequency from the midpoint of a register (modal or falsetto) the overall intensity levels and range of intensities at any one frequency will decrease. Perhaps of more importance, however, is the fact that the intensity variations found appear to relate to changes in the frequency as well as to changes in register.

As yet, no one has investigated the frequency/intensity variations which occur during vocal fry phonation. The name, vocal or glottal fry, has been given to this low frequency phonation due to the fact that perceptually it sounds like a popping or pulsing sound. As previously mentioned, the results

of Colton¹ and Stout³ indicate that the midpoint of the phonational range has the greatest intensity variation and as frequency decreases vocal intensity decreases. In vocal fry (this term will be used hereafter when referring to the low frequency range of the voice), therefore, it could be hypothesized that the intensity levels would be relatively low and the intensity ranges at any one frequency would be somewhat restricted. The purpose of this study was to investigate the frequency/intensity relationships during vocal fry phonation.

PROCEDURE

Five males and five females were chosen for the experiment on the basis of being free from voice disorders and having the ability to produce vocal fry over a range of frequencies.

The study was divided into four phases. In Phase 1, each subject's vocal fry phonational range was obtained by having the subject phonate the vowel /a/ in vocal fry at the lowest and highest frequency which he could sustain for four seconds. To obtain the lowest frequency, the subject phonated down the frequency scale until he reached the lowest frequency which he could maintain for four seconds. To obtain the upper limit, the subject phonated up the frequency scale in fry until he shifted into the modal register as judged by the experimenter and subject. He then reversed and phonated

downward again until he returned to a vocal fry frequency which he could maintain for four seconds. Only those samples were accepted which were sustained for four seconds and did not vary more than 1.5 Hertz as indicated by a Berkeley Model 554BBDK Electronic Counter (which cycled once per second).

In Phase 2, the subjects were asked to produce sustained vocal fry at a comfortable intensity level at the three frequencies; the 25, 50, and 75 percent points of their fry phonational ranges. Since vocal fry is not as common a mode of phonation as is modal phonation, it was expected that the subjects would have some difficulty in approaching the specified frequencies. From these samples, intensity readings were recorded using a General Radio Model 1551-A Sound Level Meter fed by a Bruel and Kjaer 4131 Condenser Microphone placed four inches from the subject's mouth. Three samples were obtained at each frequency region; the one which deviated the most from the other two (due to the difficulty of the task) was discarded. Thus, the final set of data in Phase 2 consisted of two samples of the vowel /a/ sustained for three seconds at three points in the subject's vocal fry phonational range.

In Phase 3, the subjects' task was to match a given intensity level in vocal fry. The target values were the mean sound pressure level readings which were obtained during the preceding phase of the study. No instructions were given regarding the frequency of the fry phonation. Both experimenter and subject monitored

the sound level meter and when they agreed that the sample was of sufficient duration and within one dB of the predetermined intensity, it was accepted.

In Phase 4, an attempt was made to determine if the subjects varied frequency as a result of changing the intensity of phonation. The subject phonated at the intensity level recorded for his low frequency sample obtained in Phase 3. When an acceptable three-second sample was produced, the subject lowered his intensity by 3 dB and sustained another sample of fry. He was given no instructions concerning frequency. Similarly, the subject phonated at the intensity level recorded for his high frequency fry sample obtained in Phase 3 and then increased the intensity level by 3 dB and sustained another sample of fry.

The subjects' fundamental frequencies for Phase 3 and Phase 4 of this study were determined by playing the tape recorded speech sample through a Visicorder and analyzing the visual write-out.

RESULTS AND DISCUSSION

The vocal fry ranges of the subjects are shown in Figure 1. The heavy lines indicate the mean ranges for males and females; the dashed lines indicate the individual variation at the high and low ends of the frequency scale. The markers along the lines indicate the mean frequencies and percentage points for the group's mean low, medium, and high phonation samples. From this figure it can be seen that greater variation existed about the high

frequency end of the subjects' ranges. It can also be seen that while the subjects did not match their 25, 50, and 75 percent frequencies, they used the approximate same frequency regions in each phase of the study. The subjects appeared to have less difficulty producing the higher frequencies within the fry range and did not tend to use the lowest one-third of their fry range. The overall mean percentage points used by the combined group for Phase 2 and Phase 3 were: Low - 41%, Mid - 62%, High - 79%.

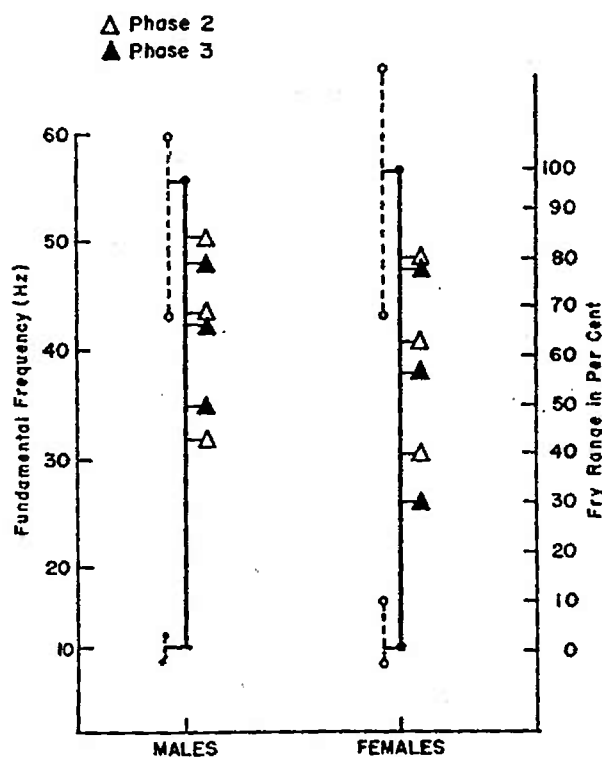


Fig. 1. The phonational ranges of both male and female subjects. The dashed lines show the variation of ranges for both groups of subjects. The markers along the vertical lines indicate the mean frequency and percentage of range used by the combined group for Phase 2 and Phase 3. Frequency is read from the left scale; percentage is read from the right scale.

Figure 2 presents the results of the vocal intensity measures as a function of the frequency of phonation for the combined group for both Phase 2 and Phase 3. For these mean values, a correlation coefficient of .88 was obtained for Phase 2 and .85 for Phase 3. A frequency/intensity correlation coefficient for each subject was also obtained and only one subject showed a coefficient that was not statistically significant at the .05 level. From Figure 2, it can be noted that the overall intensity range used was narrow.

Since the subjects did not use the lower part of their fry frequency ranges, the intensity ranges for the subjects' entire frequency range was calculated based on the curve for Phase 2 in Figure 2. This range was found to be only 9.4 dB, smaller than the intensity ranges previously obtained for modal or falsetto phonation by Colton¹. Finally, the proximity of the two functions in Figure 2 indicates that when subjects were given a predetermined intensity to match, they tended to match it at the frequency which they produced in the preceding phase carried out three to five days earlier. This suggests a possible interdependence between the regulation of frequency and intensity for vocal fry phonations.

The results of Phase 4 verify the trends shown above; that is, as subjects dropped their intensity level, a corresponding drop in fundamental frequency was also noted. As intensity was increased, frequency also increased. The results of this phase support the above conclusion that the subjects could not change vocal fry frequency without changing intensity

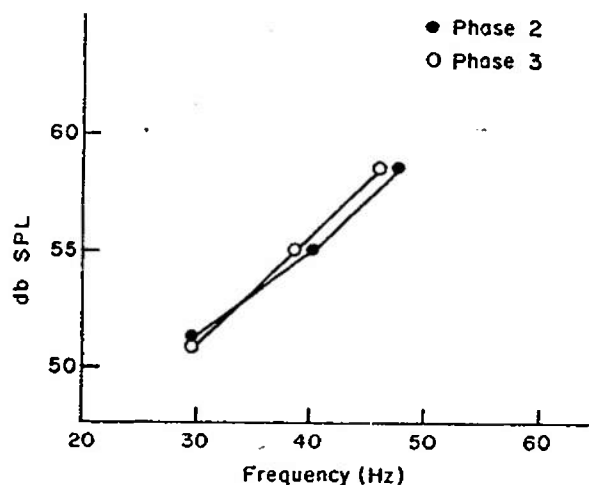


Fig. 2. Relationship between frequency and intensity of vocal fry phonation for all subjects for Phase 2 and Phase 3.

and vice versa. However, the subjects cannot be considered highly trained in the production of vocal fry and it may be that with training, frequency and intensity changes could be produced independent of each other in vocal fry just as in modal and falsetto phonation.

The results of this study suggest several similarities between the intensity regulation mechanism of sustained vocal fry and falsetto phonation. For example, Colton¹ noted that the overall falsetto intensity range is more restricted than the intensity range found in modal phonation. A relatively narrow intensity range for vocal fry was also noted in this study. Moreover, an increase in falsetto intensity accompanied an increase of frequency when the subject was phonating at his most comfortable level; this relationship was quite evident in vocal fry phonation.

Previous data dealing with the laryngeal mechanics of the falsetto and vocal fry phonations have also shown similarities. For example, the results of Hollien and Moore⁴ and Brown and Hollien⁵ indicated that there was no particular relationship between changes in the falsetto fundamental frequency and vocal fold length. Rather, these investigations have shown that lengthening of the folds (i.e., muscle contraction) is greatest in the mid-frequencies of the total phonational range or primarily the modal register. With regard to vocal fry, Hollien, Damste, and Murry⁶ have shown that vocal fold length does not increase with increases in the fundamental frequency of phonation.

The vocal fry-flow rate relationship to intensity has not yet been examined; however, Isshiki's⁷ data lend credence to the notion that air flow is not the predominant factor governing intensity changes in fry. Isshiki's results indicated that when subjects changed intensity during falsetto phonation, a change in air flow rate was observed. At the lower end of the modal register, however, a change of as much as 10 dB did not produce a change in the air flow rate. He concluded that vocal intensity during falsetto phonation is regulated by air flow rate under high expiratory pressure. Isshiki's results for the low frequency end of the phonatory scale would suggest that air flow may not be the governing factor for intensity changes in vocal fry. It may be hypothesized that the trend which he found would continue into vocal fry and air flow rate would have little effect on intensity changes. Indeed, the data

published by McGlone⁸ and Murry⁹ partially support such a hypothesis. These investigators found that for all subjects, air flow rate was highly variable both within subjects and across subjects. In Murry's study, this variability existed even while the subjects were trying to phonate in vocal fry at their most comfortable frequency/intensity points.

The implication of the above mentioned research (4-9) is that the mechanics governing the frequency/intensity changes of the vocal folds during vocal fry phonation may be somewhat similar to that of falsetto phonation and dissimilar to those governing modal phonation. However, it appears that while vocal intensity for falsetto phonation is regulated by air flow rate (Faaborg-Anderson¹⁰; Isshiki⁷) it might be hypothesized that the subglottal air pressure component is primarily responsible for regulation of intensity in vocal fry.

In conclusion, the findings of this study indicate that vocal fry is produced at low intensities in relation to intensity levels previously obtained for the modal and falsetto registers. Furthermore, it appears that frequency and intensity changes are dependent upon each other in normal sustained fry. Finally, from the results of this and previous studies, it is hypothesized that the predominant frequency/intensity changing mechanism for vocal fry is subglottal air pressure.

ACKNOWLEDGEMENT

Acknowledgement is given to Dr. W. S. Brown, Jr., of the University of Florida for his contributions to this investigation.

REFERENCES

1. Colton, R. H., "Vocal intensity in the Modal and Falsetto Registers," Journal of the Acoustical Society of America, 47, 105(A), (1970).
2. Colton, R. H., and Hollien, H., "Perceptual Differentiation of the Modal and Falsetto Registers," Journal of the Acoustical Society of America, 47, 105(A), (1970).
3. Stout, B., "The Harmonic Structure of Vowels in Singing in Relation to Pitch and Intensity," Journal of the Acoustical Society of America, 10, 137-146, (1938).
4. Hollien, H. and Moore, G. P., "Measurements of the Vocal Folds During Changes in Pitch," Journal of Speech and Hearing Research, 3, 157-165, (1960).
5. Brown, W. S. and Hollien, H., "Vocal Fold Length Characteristics Associated With Modal Falsetto and Varying Intensity Phonations," Paper presented at the Seventy-ninth Meeting of the Acoustical Society of America, Atlantic City, New Jersey, April (1970).

6. Hollien, H., Damste, H., and Murry, T., "Vocal Fold Length During Vocal Fry Phonation," Folia Phoniatica, 21, 257-265, (1969).
7. Issihiki, N., "Vocal Intensity and Air Flow Rate," Folia Phoniatica, 17, 92-104, (1965).
8. McGlone, R., "Air Flow During Vocal Fry Phonation," Journal of Speech and Hearing Research, 10, 299-304, (1967).
9. Murry, T., "Subglottal Pressure and Air Flow Measures During Vocal Fry Phonation," Paper presented at the Forty-fifth Annual Meeting of the American Speech and Hearing Association, Chicago, November, (1969).
10. Faaborg-Anderson, K., "Electromyographic Investigations of Intrinsic Laryngeal Muscles in Humans," Acta Physiologica Scandinavica, (Kbh), 41, Supplement 140, (1957).